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Kennecott Eagle Minerals
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November 3, 2009

Mr. Kevin M. Pierard
U.S. Environmental Protection Agency
Region 5
Wetlands and Watersheds Branch (WW-16J)
77 West Jackson Boulevard
Chicago, IL 60604-3507

RECEIVED

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ENVIRONMENTAL QUALITY
LAND & WATER MANAGEMENT DIV.

Dear Mr. Pierard:

RE: Response to Comments, Humboldt Mill Joint Permit Application for an Inland Lakes and Streams (ILSA) Permit, File Number 08-52-0104-P

This letter transmits Kennecott Eagle Mineral Company's ("KEMC") responses to several questions about operation of the Humboldt tailing disposal facility ("HTDF") provided to EPA in a letter from Craig A. Czarnecki of the United States Fish and Wildlife Service ("USFWS") to Sue Elston dated May 27, 2009. This letter also provides responses to comments from EPA in a letter dated June 23, 2009 to Ms. Colleen O'Keefe at the Michigan Department of Environmental Quality ("MDEQ"). Both letters were subsequently forwarded to KEMC in a correspondence dated July 2, 2009.

Should you need additional information or have questions, please don't hesitate to contact me at 906-486-1257.

Sincerely,

Vicky Peacey

Vicky Peacey
HSE Manager

cc: Ms. Sue Elston, EPA
Ms. Barb Hostler, USFWS
Ms. Colleen O'Keefe, MDEQ
Mr. Mike Smolinski, MDEQ
Dennis Donohue, Warner Norcross and Judd
Jon Cherry, Kennecott Eagle Minerals Company
Alicia Duex, Kennecott Eagle Minerals Company

KEMC Responses to U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (EPA) comments

Comments from USFWS and EPA are in italics and responses by KEMC are in regular text.

<u>USFWS Question 1:</u> The applicant proposes to place the nickel and copper tailings in slurry form subaqueously through a discharge boom from a barge floating on the surface of the HTDF. The applicant states-that this means of discharge would reduce physical mounding of the tailings. Leveling of the tailings would occur over a period of time, due to consolidation and gravity. Assuming complete leveling of the tailings, the final elevation of the tailings would be near 1,420 ft, leaving approximately 118 feet of water over the tailings, based on a surface water elevation of 1,538 ft

> *a. The applicant indicates that sampling in May 2007 showed a chemocline in the HTDF, with low DO levels below 100 feet in depth. We have concerns that 18 feet of water is a marginal layer of protection between the tailings and higher levels of DO, particularly if the tailings are not leveled as the applicant assumes. What is the likelihood that the tailings will not level and may actually rest at a higher elevation?*

<u>KEMC Response</u>:

Controlling Placement of Tailings

As stated in Special Condition F.4 in the proposed Humboldt Mill Part 632 permit, the surface elevation of the tailings shall not exceed elevation 1420 ft MSL. Additionally, as stated in the Humboldt Mill Mining Permit Application, Volume I, Section 5.3, and as per Special Condition F.7 in the proposed Humboldt Mill Part 632 permit, a bathymetric survey of the HTDF will be conducted annually to assess fill volume and confirm level placement of the tailings.

In addition to the permit conditions to ensure level placement, the following discussion will provide additional explanation and context. Mill tailings have a specific gravity greater than three and will consolidate after placement. While consolidation will help create a level surface, the most important factor affecting the final topography of the tailings surface will be initial placement. By distributing placement of tailings over the base of the HTDF as loading progresses, a reasonably level surface will be created. Consolidation after placement will continue to flatten this surface.

The effect of initial placement on the final tailings surface is visible in the cross-section of the previously placed Ropes Mine tailings (ILSA Figure 2.3). Ropes tailings were placed using a medium-density slurry (about 25% solids). Slurry was conveyed from the mill to the pit by pipeline, which discharged about 100 feet below the water surface or about 250 feet above the bottom of the original pit. Discharge was most likely near the mill on the south side of the pit. Tailings then flowed as a density wave down and across the bottom of the pit (Traverse Engineering, 1984) Discharge of Ropes tailings from a single point on the south wall of the pit produced the asymmetrical tailings surface (elevated near the point of discharge) that is still present today.

In contrast to the asymmetrical tailings placement used in the past, new tailings will be placed nearly uniformly over the current bottom of the HTDF. As described in the ILSA permit and shown in Figures 2-1 through 2-4 contained therein, tailings will be placed as a dense (about 60% solids) slurry conveyed to the bottom of the HTDF before being discharged. The point of discharge will change as barges positioning the slurry pipeline are repositioned. Tailings placement will proceed in three phases as barges are moved north to south in the HTDF. Using this placement technique, and aided by consolidation after initial placement, a reasonably flat tailings surface will be produced.

Level placement of tailings will primarily be a result of placing tailings at multiple locations within the HTDF, as described in the ILSA permit. Additional leveling will occur as tailings consolidate. As placement is being done in a purposeful way with the intent of creating a level surface, it is anticipated that the tailings surface will be reasonably level soon after placement is complete. This will be confirmed through the annual bathymetric surveying, and adjustments to the deposition plan made, to the extent required on the basis of those results.

An estimate of the scale of local relief across the surface of the placed tailings can be made by considering the historical example provided by the Ropes tailings. Ropes tailings were placed without regard to flatness of the final surface. The tailings were placed near the wall of the pit, with the unintended consequence of creating a surface with near-maximum local relief due to mounding supported by the pit wall. As a result of this placement process, Ropes tailings display a local relief of roughly 50 feet.

Placing tailings at multiple locations in the HTDF will reduce mounding as tailings flow between placement locations. New tailings will be placed by two barges in three phases (ILSA Figure 2-1), creating a minimum of six placement locations (barges may also move during a placement phase, increasing placement locations). Placement will be near the center of the HTDF away from walls. Given these components of the placement plan for new tailings, it is reasonable to expect local relief of the new tailings surface to be much less than that displayed by the Ropes tailings. Based on minimum placement locations, local relief would reasonably be expected to be less than one-sixth that exhibited by the Ropes tailings, or less than 10 feet.

Control of Sulfide Oxidation by Subaqueous Disposal

The following discussion addresses the concern that 18 feet of water is a marginal layer of protection between the tailings and higher levels of DO. Disposal of acid generating materials below a water cover has a demonstrated record as an effective method for preventing the oxidation of sulfide tailings. According to the Mine Environmental Neutral Drainage (MEND) Program (February, 2001), subaqueous systems are an effective stable environment for sulfides, not because they are completely devoid of oxygen, but because they contain low oxygen levels even at their most saturated state.

In natural waters, the maximum concentration of dissolved oxygen is approximately 30 times less per liter of fluid (water or air) than in the atmosphere (MEND, 2001). More importantly, the transport of oxygen through water by advection and diffusion is severely limited relative to transport in air. Because the rate of sulfide oxidation in aqueous systems at circum-neutral pH is dependant on the concentration of oxygen (Williamson, M.A. and J.D. Rimstidt, 1994), the generation of acid and dissolved metals is dramatically minimized under water compared to rates observed at ground surface or in forced-air (e.g., "humidty-cell") experiments. Unless oxygen is present in at least the minimum stoichiometric excess over sulfides, it will be the limiting reagent in an aqueous system. A simple stoichiometric calculation for the oxidation of pyrite by molecular oxygen (i.e., as dissolved oxygen) shows that for an initial concentration of 10 mg/L O_2 (3.125E-4 O_2 mol/L), the equilibrium concentration of dissolved sulfate generated would be 17 mg/L (1.79E-04 mol SO_4^{2-}/L)[1].

More important, the very slow rate (diffusive transfer of oxygen in water is on the order of 10,000 times slower than diffusive transfer in air (MEND, 2001)) controls the replacement of O_2 at the sediment water interface. As a result, storage under permanent water cover is perhaps the single most effective measure that may be taken to inhibit acid generation from sulfidic tailings, regardless of whether the water is anoxic or fully oxygenated. If pyrite oxidation is controlled, then the alkalinity of the water will buffer pH at levels that will control the activity of Fe^{3+} to minute concentrations, and so only the initiating reaction, abiotic oxidation by molecular oxygen, is relevant.

It is important to note that oxygen depletion and even anoxia at depth in the HTDF is an added benefit, but for the reasons highlighted above, it is not a required condition for successful subaqueous tailings disposal because sulfide minerals oxidize extremely slowly when submerged under oxygen-bearing waters. Under a water cover, even when the water is fully oxygenated, oxidation of sulfides is very slow and in most cases sulfides can be considered unreactive in circum-neutral, subaqueous environments.

As a result of the controlling effect of dissolved O_2 on sulfide oxidation, only relatively thin water covers with circum-neutral pH, even fully oxygenated, are needed to effectively prevent oxygen diffusion and subsequent oxidation of sulfide tailings. Research examining the behavior of water covers (referenced in the ILSA permit application) has demonstrated that shallow water covers (centimeters of depth) are very effective at limiting oxidation of tailings, despite the fact that water in these shallow covers is fully oxygenated. The results of numerous field and laboratory tests show that the body of evidence demonstrates that water covers are effective in preventing sulfide oxidation and acid generation (MEND, 2001).

> *b) Will the discharge boom place the tailings directly on the bottom of the HTDF, or will the tailings settle, at least partially, through the well-oxygenated water column above 100 feet? If the tailings do settle through the water column, how will this affect the chemical equilibrium of the HTDF? Will this increase the bioavailability of metals?*

KEMC Response:

As described in the response to Question 1a, tailings will be placed as a dense (about 60% solids) slurry conveyed to the bottom of the HTDF before being discharged. The discharge boom will be placed 100 feet below the pit water surface, so tailings will settle only through the oxygen depleted portion of the water cover and will settle relatively quickly to the bottom (tailings specific gravity is > 3.0).

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[1] $FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2H^+$. Then $[SO_4^{2-}] = 2/7 * (2* [O_2]$, where the quantities in parentheses are activities of aqueous species, and we assume that activity and concentration are essentially identical in dilute solutions.

Even if tailings settled fully or partially through the oxygenated water column above 100 feet, which is not the KEMC deposition design, they would not oxidize significantly since water covers are effective because of the low solubility and diffusivity of oxygen in water (see 1a, above). This is especially true in the kinetically-controlled pass-through system of sinking solid grains where the reaction can occur only while the grains are settling. As stated above, oxygen depletion and anoxia in the deep portion of HTDF where the tailing will deposit is an added benefit, but it is not a required condition for successful subaqueous tailings disposal because sulfide minerals oxidize extremely slowly when submerged under oxygen-bearing waters. Even at their most saturated state, oxidation of sulfides under a water cover is very slow, and combined with the relatively high specific gravity and high density tailings slurry, there would not be sufficient reaction time for the sulfide tailings to substantially oxidize. Because the system is protective geochemically against sulfide oxidation there would be de minimis risk of release of any trace metals present in the sulfides.

<u>USFWS Question 2</u>: *The applicant indicates the HTDF does receive some inflow from groundwater.*

> *a. Will adding 75 feet of mine tailings to the HTDF alter the groundwater flow into the HTDF? If the groundwater inflow is decreased, is precipitation enough to maintain the surface water elevation at 1,538 feet? If the surface water elevation decreases, will the water cover over the tailings be sufficient to prevent oxidation?*

<u>KEMC Response</u>:

Please see Attachment 1 in response to the first question. Although it is not anticipated to occur, it is reasonable to say that even if the water cover elevation in the HTDF decreased due to drastically reduced groundwater inflow (i.e. drought conditions) the water cover depth over the tailings would be more than adequate to prevent sulfide oxidation. KEMC responses 1a and 1b above address the question of adequate water cover for prevention of oxidation.

Table 2a shows a simple water balance for the HTDF. Using existing hydrogeological conditions (average annual precipitation, runoff and groundwater input and groundwater discharge output) the pit is balanced with a typical water surface elevation 1,538 ft above MSL. Groundwater represents only 17% of the total water balance, and almost all of that is shallow alluvial flow.

Under drought conditions (from historical records) and no modification to downgradient groundwater discharge, the pit would experience some net decline in water surface elevation as the water balance shows a net decrease (flow out is greater than flow in on an annual average in this case).

However, the groundwater seepage out is planned to be controlled and cut-off with a low-permeability cut-off wall installation, that is planned to reduce seepage out of the HTDF to less than 1 gpm. As a result of the cut-off wall installation, a surface water discharge is maintained in the water balance, although reduced to balance the decreased input experienced in an extreme drought year. Therefore, no significant head decrease is anticipated to occur in a drought year condition, although the total volume of surface water flow out of the pit will be significantly decreased.

Table 2a. HTDF Water Balance During a Drought Year

Average Year[1]	Data	Drought Year
Inputs		
Annual Precip (in)	33	20
Annual Precip (ft)	2.8	1.7
ET %	45%	60%
Basin Area (acres)	224	224
Annual Runoff to Basin (in)	18.2	8
Annual Runoff to Basin (ft)	1.5	0.7
Annual Runoff Vol (acre-ft)	338.8	149.3
Annual Ave GW in (acre-ft)	69.0	30.0
Total input (acre-ft)	407.8	179.3
Annual ave flow rate (cfs)	0.56	0.25
Annual ave flow rate (gpm)	253	111
Outputs		
Without cut-off wall		
GW seepage (gpm)	253	253
BALANCE	0	-142
With cut-off wall		
GW seepage (gpm)	0.01	0.01
Surface Water (gpm)	253	111
BALANCE	0	0

1. Data Source: USGS (1981) and Foth (2008).

b. We anticipate that the groundwater contains dissolved oxygen. How does this affect the potential oxidation of the tailings? Will the oxygenated groundwater mobilize metals, and will these metals enter the groundwater?

KEMC Response:

The tailings will be placed within the HTDF and largely adjacent to the lower bedrock unit. As described in the response to Question 3 below (Attachment 1), the results of bedrock core analysis, single well pumping tests, and water quality in bedrock around the HTDF support the use of the term aquitard for the upper bedrock and aquiclude for the lower bedrock which surrounds the HTDF. All available data strongly suggests that the lower bedrock surrounding the HTDF is a very low permeability, isolated hydrostratigraphic unit and no significant amount of water from the bedrock will enter or exit the HTDF.

The only significant groundwater input to the pit is from the upgradient quaternary aquifer source. The wells that provide samples representative of this water quality are HW-3 and HW-4. As shown on attached Table 2b, samples from both of these wells show dissolved oxygen levels measured in the field less than the detection limit used (0.1 ppm). The shallow (surface) pit water has dissolved oxygen levels at or near saturation (greater than 8 ppm). It is apparent from the comparison of these data that groundwater does not provide a significant contribution of dissolved oxygen to the pit currently and will therefore also not provide a contribution of significance during or after tailings disposal. As discussed in the answer to Question 1a, oxygen would rapidly become a limiting reagent, and because the DO of the deep groundwater is so low, its initial impact is very much less than the greater than 8 ppm case discussed above.

Table 2b. Summary of DO Measured in the HTDF and Quaternary Aquifer Wells Up-gradient and Down-gradient of the HTDF.

Location	DO (ppm)[1]			n
	Mean	Max	Min	
Quaternary Aquifer Wells				
Downgradient of Pit				
HW-1	<0.1	<0.1	<0.1	4
HW-1A	5.6	8.9	0.3	4
HYG-1	4.4	7.5	0.3	4
HW-2	0.2	0.4	<0.1	4
HW-5	<0.1	<0.1	<0.1	4
HW-5A	5.1	7.5	0.3	4
HW-6	<0.1	0.1	<0.1	4
HW-6A	2.0	6.0	<0.1	4
Upgradient of Pit				
HW-3	<0.1	<0.1	<0.1	4
HW-4	<0.1	<0.1	<0.1	4
Pit Water				
HPL-3_3'	9.3	11	8.0	7
HPL-3_15'	9.4	11	8.0	7
HPL-3_60'	8.5	9.7	7.0	7
HPL-3_120'	0.2	0.5	0.05	7
HPL-3_175'	0.1	0.2	0.05	7

1. In some cases DO values were measured at values lower than <0.1 ppm. For this comparison a reporting limit of 0.1 ppm was used for all measurements and values less than 0.1ppm were converted to 0.05 (1/2 the reporting limit) to calculate statistics.

USFWS Question 3: The applicant proposes to construct a slurry wall and berm to prevent groundwater and surface water from leaving the HTDF. We have concerns that groundwater could leave the site and gain access to surface waters. Is there fractured bedrock that would allow groundwater seepage at other locations than the proposed slurry wall? We recommend the applicant clarify the potential for groundwater seepage from the HTDF.

KEMC Response:

Please see Attachment 1 for the complete response.

USFWS Question 4: In Appendix B, the applicant states that N_{df} in equation (4) is very small, indicating significant temperature stratification in the HTDF; however, the applicant does not provide any values used for the variables in the equation. Moreover, the equation suggests that N_{df} should decrease as the average depth increases. But, the applicant provides information that in 1984, prior to placement of tailings from the Ropes Mine, the DO levels were much higher at the bottom of the pit, even though the HTDF was much deeper then, indicating mixing of the waters during spring and fall turnover. Thus, we question the validity of the calculated value for N_{df} and the assertion that the HTDF is not likely to mix due to insufficient turbulence. We recommend the applicant provide the data used to calculate N_{df} and answers to the following questions:

a. *Has equation (4) been field validated for applicability to temperate lakes?*

b. *How are wind forces taken into account in the inputs to equation (4)?*

c. *Why did mixing apparently occur in the past (as evidenced by high DO levels at the bottom) when the HTDF was deeper? How will decreasing the depth of the HTDF by another 75 feet affect the N_{df}?*

d. *The equation indicates that N_{df} should become larger as the volume flow (Q) increases. How will the displacement of water from the discharge of tailings affect the value of Q and ultimately N_{df}?*

e. *With wind, decreased depth, and increased outflow taken into account, would you still predict a stable system?*

KEMC Response:

Please see Attachment 2 for the complete response.

USFWS Question 5: *Appendix B provides a model for chemical concentrations in the HTDF in the event of complete mixing. The applicant indicates this represents a "worst-case" scenario and should aid in the design of the proposed waste water treatment plant. Table 4 presents the expected concentrations of chemical constituents with complete mixing. Several of these expected concentrations, including those for barium, cobalt, copper, iron, lead, manganese, mercury, and nickel, exceed the freshwater chronic screening values for aquatic life (Buchman 2008). Although the applicant can presumably design a treatment plant to remove these chemicals before waste water is discharged from the HTDF, the applicant does not consider the potential impacts of these concentrations while in the HTDF. As we have concerns about the likelihood of complete mixing occurring in the HTDF, we recommend the applicant provide an analysis of the impacts to aquatic life and effects at higher trophic levels from these expected concentrations in the HTDF.*

KEMC Response:

As stated in the letter by USFWS, there is concern that fish in the HTDF may contain elevated metals concentrations under a complete mix scenario. While it is not expected that the complete mix scenario can occur due to the highly stable aquatic system within the deep HTDF pit (see Attachment 2), the complete mix scenario did result in predictions of high concentrations of some metals, particularly copper and nickel. It was suggested that fish exposed to these high concentrations may be available to scavengers or piscivorous birds foraging in the HTDF resulting in exposure to high metals concentrations. In this connection it is important to note that the HTDF will be closely monitored throughout the duration of mill operations and after reclamation of the mill site. Therefore, the potential for the unlikely, worst case complete mix scenario will be known before it occurs. Kennecott will therefore have the ability to develop and implement measures that minimize the impacts of such an event, such as fish harvesting or other measures to prevent eagles and other predatory species from exposures to impacted fish within the HDTF.

A critical component of the evaluation of risk to bald eagles or other picivorous birds is a complete exposure pathway of contamination to the receptors. There are several reasons why it is expected that this pathway will be incomplete for the HTDF. First, concentrations under the conservative and unlikely complete mix scenario are high enough that it would not be expected that fish would survive under those conditions, removing the food supply from the HTDF. Further, bald eagles occupying interior regions are known to prefer foraging on benthic-feeding fish (Dunstan and Harper 1975; Todd et al. 1982; Haywood and Ohmart 1986; Watson et al. 1991) and bald eagle foraging success is greatest in shallow water (Watson et al. 1991). The steep walls of the HTDF do not provide sufficient shallow water habitat to promote frequent bald eagle foraging success. Compared to other nearby surface waters, such as Lake Lory and the Middle Branch of the Escanaba River, the HTDF system is characterized by relatively little shallow-water area, smaller sized fish, and lower system productivity. The lower system productivity in the HTDF can readily be observed in a fish community that is relatively low in diversity when compared to Lake Lory and the Middle Branch of the Escanaba River. A system that is characterized by low system productivity is not likely to be a primary forage location for birds like bald eagles that require an abundant food supply (Haywood and Ohmart 1986). Because bald eagles are not likely to forage frequently within the HTDF (e.g. due to water depth), the likelihood of fish from the HTDF becoming a significant portion of their diet is expected to be low.

Finally the foraging range of eagles will either preclude exposure to the HTDF for brooding pairs or minimize exposure for winter home ranges (EPA, 1993). More specifically, an eagles nest had been observed at Lake Lory some miles from the HTDF, and it was suggested that these eagles may be exposed to metals in fish from the HTDF. During brooding season the foraging range of eagles is small (e.g., 1-2 acres), so it is more likely that the eagles associated with this nest were foraging from Lake Lory, and would not fly the distance to the HTDF. Further, during winter eagles exhibit a large foraging range of some 4,000 to 5,000 acres. Even if this range included the HTDF, the 65 acre HTDF represents a very small proportion of surface water within the entire range, and that small surface area is not expected to have substantive fish populations for consumption.

In summary the HTDF does not represent habitat conductive to producing fish that would constitute a substantial proportion of an eagles diet. Further it is likely that because the HTDF is small relative to an eagles' non-brooding habitat, it is unlikely that significant fishing would occur at the facility. Based upon this information, it is expected that any ecological risk to eagles or piscivorous birds from any exposure to fish from the HTDF is *de minimus*.

<u>USFWS Question 6</u>: *In addition to our concerns about disposal of the tailings in the HTDF, we also have concerns about the applicant's proposal to discharge 13,500 cubic feet of treated water per day into adjacent wetlands. We have concerns that this increased volume of water into the wetlands will make the area too wet to continue to support an emergent/scrub-shrub community, changing the wetland to an open water system. We recommend the applicant demonstrate that this increased volume would not affect the plant community or else consider alternatives to discharging treated water into the wetlands. We recommend compensatory mitigation for any unavoidable impacts to the adjacent wetlands, including conversion to another wetland type.*

<u>KEMC Response</u>:

Please see Attachment 3, which contains KEMC's response to this question which was submitted to MDEQ in a letter dated August 13, 2009.

EPA Question 1: It has been well documented that increases in volume and/or frequency of surface water inputs to wetlands can degrade wetland plant communities. In this case the addition of a significant amount of water to the wetlands is likely to result in the degradation and/or destruction of the vegetated wetlands community, possibly resulting in the creation of a large open water area. The conversion of a vegetated wetland community to open water would result in habitat loss and possibly water quality benefits as well. The applicant needs to demonstrate that there are no alternatives available that would be less damaging to these wetlands. If no alternative is available, than pursuant to the Section 404(b)(1) guidelines, the applicant needs to mitigate for unavoidable adverse impacts.

KEMC Response:

Please see Attachment 3, which contains KEMC's response to this question which was submitted to MDEQ in a letter dated August 13, 2009.

Literature Cited

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ATTACHMENT 1

Responses to USFSW Questions 2 and 3

North Jackson
Company
1004 Harbor Hills Dr., Suite 102
Marquette, MI 49855
906.225.6787

Technical Memorandum

July 20, 2009

To: Victoria Peacey, Kennecott Eagle Minerals Company

From: Dan Wiitala, North Jackson Company

RE: **Humboldt Mill Project Part 301 Inland Lakes and Streams Permit Application, MDEQ File No. 08-52-0104-P**

1. Introduction

North Jackson Company has prepared this technical memorandum (memo) on behalf of Kennecott Eagle Minerals Company (KEMC) in response to certain questions regarding its permit application under the Michigan Department of Environmental Quality (MDEQ) Part 301, Inland Lakes and Streams, of the Natural Resources and Environmental Protection Act 1994 PA 451, as amended. Specifically, the information contained in this memo is intended to address the following questions in a letter from US Department of the Interior, Fish and Wildlife Service to Ms. Sue Elston (USEPA) dated May 27, 2009:

2. Response to Questions

Page 2, Item 2. *The applicant indicates the HTDF does receive some inflow from groundwater. A. Will adding 75 feet of mine tailings to the HTDF alter the groundwater flow into the HTDF? If the groundwater inflow is decreased, is precipitation enough to maintain the surface elevation at 1,538 feet?.*

The approximate direction of the groundwater flow gradients for upper bedrock groundwater flow and alluvial, unconsolidated aquifer flow are indicated by flow arrows shown on Figures 1 and 2, respectively. A hydrogeological cross section with groundwater potentiometric contours is presented in Figure 3. In both bedrock and unconsolidated systems, the direction of the gradient is towards the HTDF from the south, east and west, and away from the HTDF at the north end. The proposed operation of the HTDF and the addition of tailings will not change the direction of groundwater seepage into the HTDF.

Water balance modeling of operational conditions indicates that normal annual variations and peak annual flows (runoff) will not cause excessive HTDF water elevation fluctuations (Humboldt Mill Part 632 Permit Application, Volume IA, Appendix D). The current pit water level is maintained within a very stable range of 1,537 to 1,538 ft (above mean sea level) by the existing water balance mechanisms. Simulated operational HTDF water levels for average annual hydrologic budget years were less than 1,539.1 ft. The HTDF level modeled for a 100-year, 24-hour storm event was shown to raise the water elevation temporarily about 1.21 ft.

Water will be conveyed from the HTDF via the waste water treatment plant (WWTP) and discharged via the outfall at the north end of the HTDF. Using this control mechanism the HTDF water elevation will not be significantly changed from current conditions following the installation of the containment wall. Therefore there is no significant change to existing

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gradients predicted or expected and groundwater inflow is not expected to decrease. Also, the control berm at the north end maintains water elevation at or below 1,543 ft so the HTDF water level also will not reasonably be expected to rise above that elevation.

Page 3, Item 3. *The applicant proposes to construct a slurry wall and berm to prevent groundwater and surface water from leaving the HTDF. We have concerns that groundwater could leave the site and gain access to surface waters. Is there fractured bedrock that would allow groundwater seepage at other locations that the proposed slurry wall? We recommend the applicant clarify the potential for groundwater seepage from the HTDF.*

The proposed location of the containment wall is shown relative to existing alluvial, unconsolidated aquifer potentiometric surface contours in Figure 4. Based on the HTDF water balance (Hydrologic and Geochemical Mass balance Model Report, Humboldt Mill Part 632 Permit Application, Volume IA, Appendix D) and the current design considerations for the cutoff wall with a thickness of four feet, an average hydraulic conductivity in the range of 10^{-7} cm/s, and a wall area of 97,000 square feet (Attachment B11, May 2009 Response to MDEQ Comments, Humboldt Mill Part 632), flow through the cut-off wall has been estimated at approximately 0.6 gpm on an annual basis (estimate from Foth I&E analytical calculations). Compared to the current flow through the unconsolidated materials at the north end of the HTDF estimated with the same analytical method under existing conditions (246 gpm), the proposed cutoff wall will decrease mixing of untreated HTDF water with alluvial groundwater by a factor of approximately 400 and thus will be 99.7% effective in preventing HTDF groundwater mixing relative to current conditions (Foth I&E analytical calculations). This operational condition is anticipated to improve existing groundwater quality in the alluvial aquifer north of the HTDF.

The groundwater flow to the area north of the HTDF that is cut-off by the containment wall will be replaced by wetland recharge from the WWTP discharge, thus groundwater flow direction will be very minimally affected by the cut-off wall north of the HTDF. The direction of the alluvial aquifer flow system gradient will still ultimately be controlled by the Escanaba River watershed gradients.

As a result, no significant change in groundwater gradients is expected from the containment wall and WWTP discharge.

The bedrock adjacent to the Humboldt Mill Tailings Disposal Facility (HTDF) was described as an "aquitard" in the MPA (Humboldt Mill Part 632 Permit Application, Volume II J – *Bedrock Hydrogeological Characterization Report*). This classification was based on a comparison of hydraulic parameter test data (transmissivity and calculated hydraulic conductivity) of both bedrock and unconsolidated formations that are present immediately adjacent to the pit. Based on these data, the nomenclature used to describe these formations was selected following the vocabulary conventions proposed in the classical text Groundwater (Freeze and Cherry, 1979). This text uses aquifer, aquitard and aquiclude to describe formations capable of transmitting significant amounts of water; formations that are less permeable but capable of some transmission of water regionally; and formations which are incapable of transmitting significant amounts of water, respectively. All definitions assume normal (undisturbed) hydraulic gradients.

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Freeze and Cherry state that the definitions are somewhat imprecise and best used in a relative sense within a defined context of study. However, they also point out that the term aquifer is generally reserved for formations with hydraulic conductivity greater than about 10^{-5} centimeters per second (cm/s), which is usually found in unconsolidated sands and gravels, permeable sedimentary rocks (sandstone and limestone) or heavily fractured volcanic and crystalline rocks.

Regionally bedrock formations in the Humboldt Mill area, and locally around the pit, are only capable of poor yield to wells. Well yield generally decreases with depth of installation. Specific capacity for the bedrock test wells around the pit ranged from 0.004 to 0.019 gallons per minute per foot (gpm/ft). Well productivity rates below 0.01 gpm/ft are generally considered poor to infeasible for domestic (residential) supply rates (US Department of the Interior, 1977) and therefore are associated with formations not considered to be aquifers. The only bedrock test wells with yields above this threshold were upper bedrock test wells HW-1U and HW-5U (0.011 gpm/ft and 0.019 gpm/ft, respectively) located at the north end of the pit (Figure 1) in the vicinity of the cutoff wall. In contrast, monitoring wells installed in overlying unconsolidated alluvial formations adjacent to the pit are capable of well yields 100 to 1,000 times higher than the bedrock formations, and in this context the unconsolidated formations may be considered aquifers while the bedrock is an aquitard.

The results of the bedrock core analysis and single well pumping tests around the HTDF confirm the regional data, indicating the existence of two primary hydrostratigraphic zones within the low permeability bedrock. The bedrock is overlain by much more transmissive unconsolidated alluvial aquifer formations (composed of a large percentage of sand) at the north and south ends of the pit. The upper bedrock geometric mean hydraulic conductivity estimates are 1×10^{-6} cm/s for pumping phase tests and 4×10^{-7} cm/s for recovery phase tests. The lower bedrock geometric mean hydraulic conductivity estimates are 3×10^{-7} cm/s for pumping phase tests and 2×10^{-7} cm/s for recovery phase tests. The geometric mean value of hydraulic conductivity of the unconsolidated formations overlying bedrock is 2×10^{-3} cm/s, three to four orders of magnitude higher than the mean values for the bedrock intervals tested around the pit.

These findings support the use of the term "aquifer" for the transmissive unconsolidated alluvial formations and "aquitard" for upper bedrock formations surrounding the pit. Lower bedrock hydraulic test data support a conclusion that lower bedrock likely meets the definition of "aquicludes" (incapable of transmitting significant amounts of water), with hydraulic conductivity on the order of 10^{-8} cm/s. Low level environmental isotope (tritium) data also support a determination that the lower bedrock (represented at location HW-1L) is "not vulnerable" to contamination from surficial water sources based on its tritium concentration of 1.0 tritium unit (TU) (MDEQ, 2007). This low level of tritium indicates that the deep bedrock is isolated from surficial water sources. This is consistent with hydraulic test data and as well as major ion chemistry data that all indicate the lower bedrock is a very low permeability, isolated hydrostratigraphic unit.

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Flux from the HTDF directly into the upper bedrock has been estimated using a Darcy's law approach and a simplified flow net analysis. Using this method, and assuming that the average bedrock hydraulic conductivity measured in field pumping tests (1×10^{-6} cm/s or 3.3×10^{-8} ft/s) applies to the upper 100 ft of bedrock, the mass flux through the system is 4×10^{-5} ft^3/s (0.02 gpm). In comparison to the flux estimated through the alluvium based on measurement downgradient from the HTDF, about 265 gpm, (Humboldt Mill Part 632 Permit Application, Volume II I – *Humboldt Mill Basin Integrity and Vertical Stability of the Humboldt Tailings Disposal Facility*), this flux is about 0.01% of the estimated flux out of the HTDF, and well below a level of significance for the water budget estimate. This estimate supports the assumption used in the water balance calculations that bedrock water flux in this geological environment is negligible in comparison to net precipitation and alluvial aquifer flux.

Groundwater in the upper bedrock is not expected to reach any surface water features or the overlying unconsolidated aquifer. This conclusion is based on the hydraulic testing data and analyses. Bedrock groundwater moves at a very low average linear velocity and mass flux, as described above.

All vertical gradients between the unconsolidated alluvium and between the upper and lower bedrock hydrostratigraphic units are downward. The vertical gradient at the north end of the HTDF is visualized with the potentiometric contour cross sectional view shown for the long axis of the HTDF in Figure 3. These downward gradients will not be altered during HTDF operation, therefore groundwater in the bedrock system is not anticipated to discharge to surface water or wetlands north of the HTDF.

Attachments

4 Figures

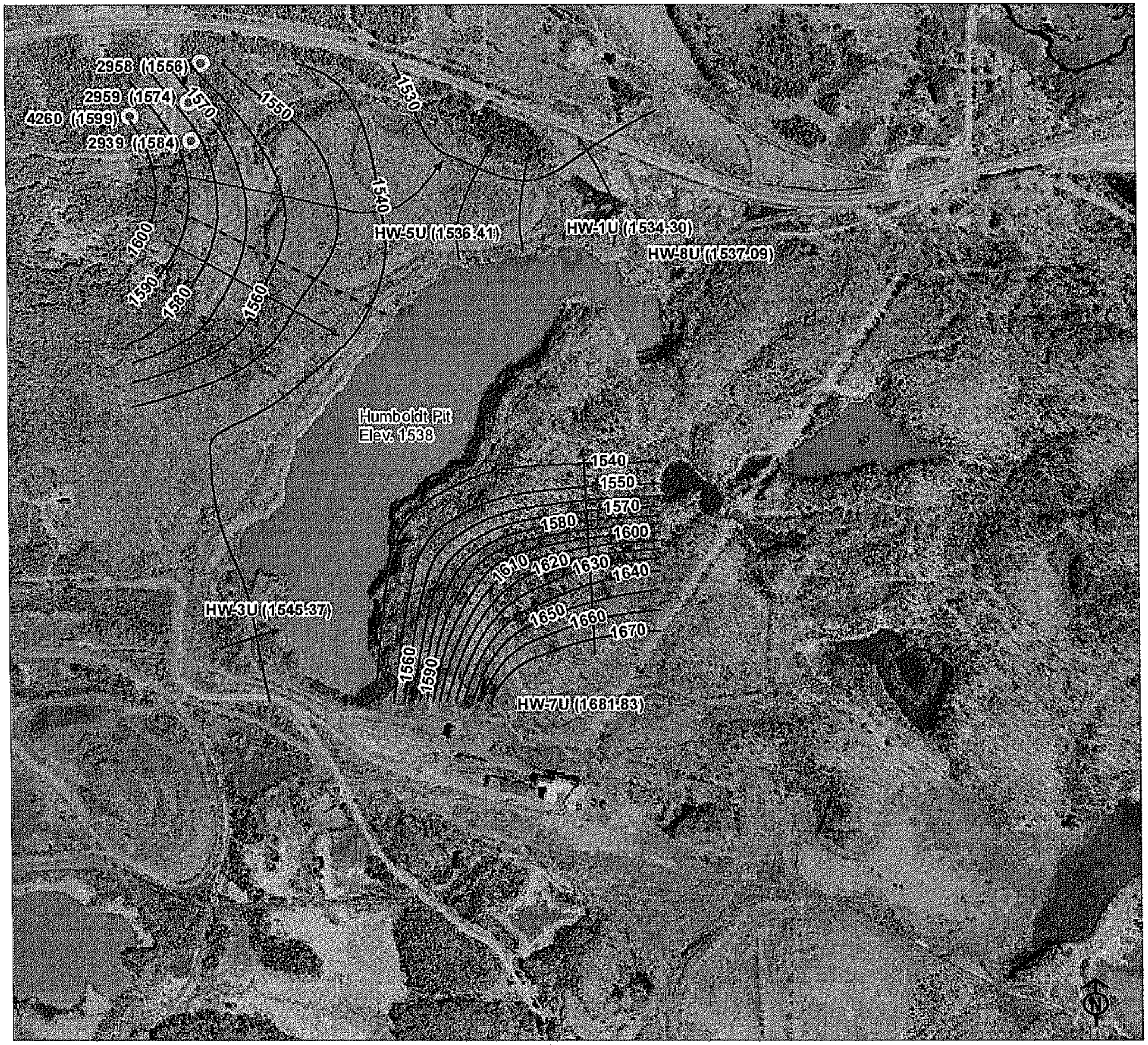

Figure 1
UPPER BEDROCK POTENTIOMETRIC SURFACE MAP HUMBOLDT HTDF

Legend

- Monitoring Well
- (1534.30) Groundwater Elevation (ft MSL on 12/2/09)
- Residential Wells (2958) Wellogic ID
- Humboldt Groundwater Elevation Contour (10' interval)
- Flow Line
- Flow Divide

0 500 1,000 Feet

Scale 1:12,000
1" = 1,000'

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Figure 2
ALLUVIAL AQUIFER POTENTIOMETRIC MAP HUMBOLOT HTOF

Legend

Monitoring Well (1556.51) Groundwater Elevation (ft MSL on 06/05/07)

Groundwater Elevation Contour (Contour Interval 10 ft to the south 1ft to the north of the Pit)

Flow Line

Bedrock Outcrop

0 500 1,000 Feet

Scale 1:12,000
1" = 1000'

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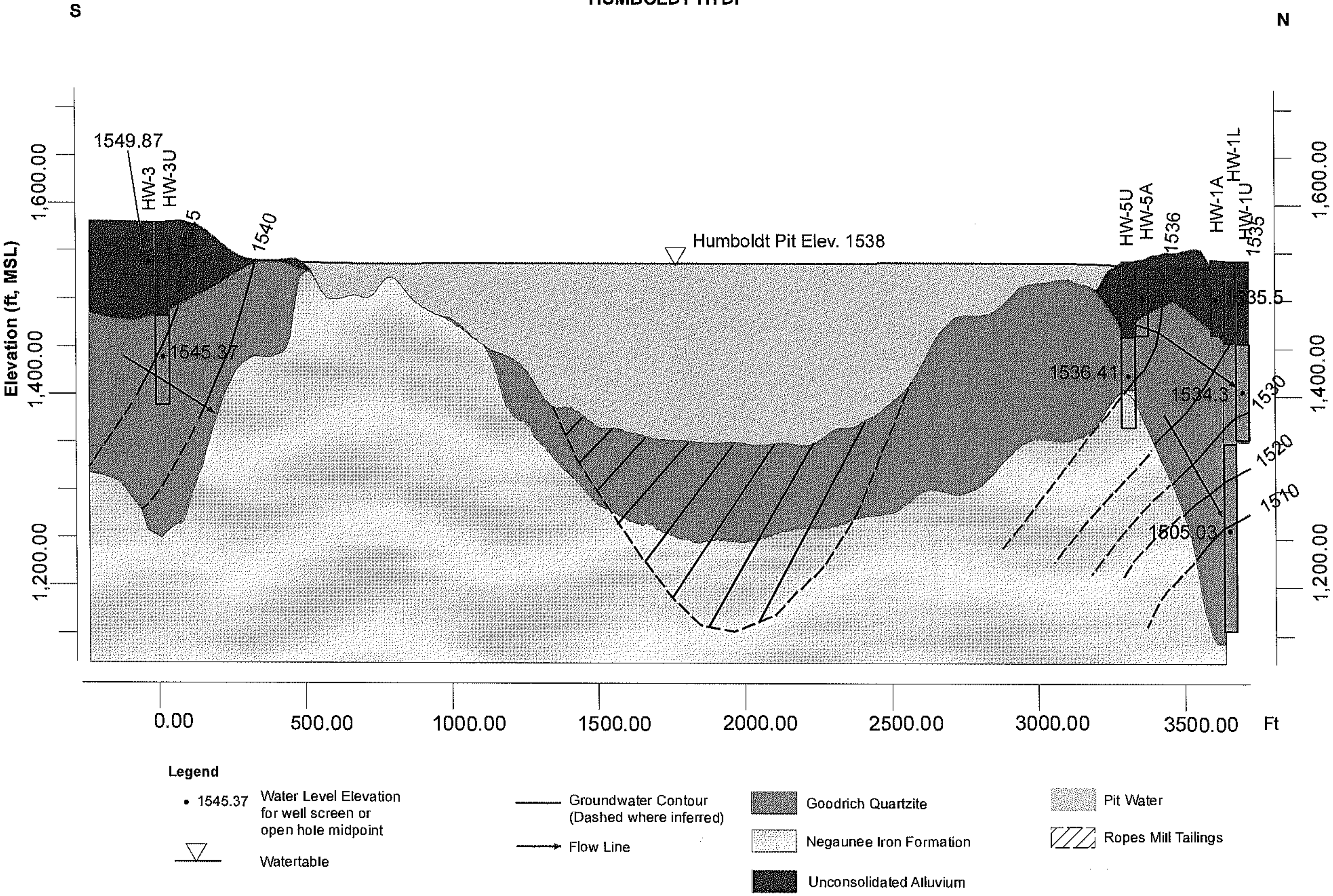
Figure 3
CONCEPTUAL HYDROGEOLOGICAL CROSS SECTION
HUMBOLDT HTDF



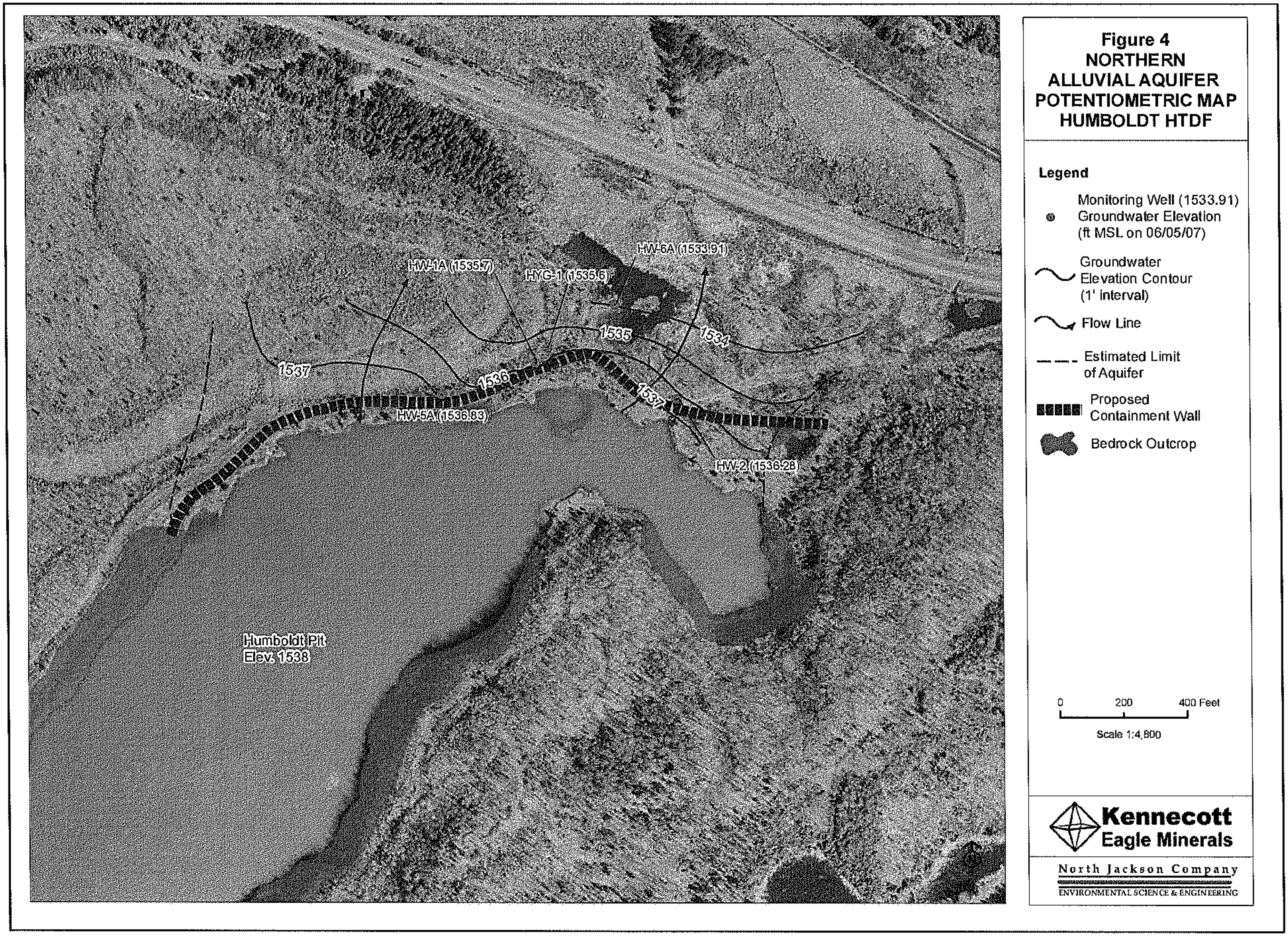


Figure 4
NORTHERN ALLUVIAL AQUIFER POTENTIOMETRIC MAP HUMBOLDT HTDF

ATTACHMENT 2

Response to USFSW Question 4

Foth

Memorandum

August 3, 2009

TO: Victoria Peacey, Kennecott Eagle Minerals Company

CC: Steve Donohue, Foth Infrastructure & Environment, LLC
Master File: 06W003-5001

FR: Jon Manchester, Foth Infrastructure & Environment, LLC

RE: Question 4 in USFWS May 27, 2009 Letter ILSA permit application

Purpose

This memorandum provides a response to questions concerning the Humboldt Mill Inland Lakes and Streams permit application raised in a letter dated May 27, 2009 from the US Department of the Interior, Fish and Wildlife Service to Ms. Sue Elston of the US Environmental Protection Agency, and forwarded to Kennecott Eagle Minerals Company by the Michigan Department of Environmental Quality on July 2, 2009. Only question 4 in the above referenced letter is addressed in this memorandum.

Question 4

In Appendix B, the applicant states that N_{DF} in equation (4) is very small, indicating significant temperature stratification in the HTDF; however, the applicant does not provide any values used for the variables in the equation. Moreover, the equation suggests that N_{DF} should decrease as the average depth increases. But, the applicant provides information that in 1984, prior to placement of tailings from the Ropes Mine, the DO levels were much higher at the bottom of the pit, even though the HTDF was much deeper then, indicating mixing of waters during spring and fall turnover. Thus, we question the validity of the calculated value for N_{DF} and the assertion that the HTDF is not likely to mix due to insufficient turbulence. We recommend the applicant provide the data used to calculate N_{DF} and answers to the following questions:

a. Has equation (4) been field validated for applicability to temperate lakes?

b. How are wind forces taken into account in the inputs to equation (4)?

c. Why did mixing apparently occur in the past (as evidenced by high DO levels at the bottom) when the HTDF was deeper? How will decreasing the depth of the HTDF by another 75 feet affect the N_{DF}?

d. The equation indicates that N_{DF} should become larger as the volume flow (Q) increases. How will the displacement of water from the discharge of tailings affect the value of Q and ultimately N_{DF}?

e. With wind, decreased depth, and increased outflow taken into account, would you still predict a stable system?

General Discussion of Question 4

The central concern expressed in Question 4 is that the vertical stability indicated by the densimetric Froude number (Froude number) (N_{DF}) is not sufficient to prevent mixing of the HTDF water column. Initial discussion in this response will address this concern and provide additional information regarding water column vertical stability. Answers to specific questions follow this general discussion.

The Froude number is a dimensionless ratio comparing inertial and gravitational forces acting on a body of water. A ratio greater than one indicates that turbulence due only to flow through the basin is sufficient to mix the basin, despite stabilization due to water density vertical stratification. Conversely, a ratio less than one indicates that density vertical stratification will prevent basin flow from mixing the basin.

It is important to recognize that N_{DF} considers only mixing due to flow of water through the basin. Wind-driven mixing is not considered in the Froude number analysis. As such, N_{DF} provides an initial analysis of basin vertical stability. If basin flow produces basin mixing (indicated by N_{DF} greater than one), no further analysis is required as the basin will not maintain density vertical stratification even in the absence of wind-driven turbulence. However, if basin flow alone cannot disrupt density vertical stratification and cause basin mixing (indicated by N_{DF} less than one), than vertical stratification will persist over long periods of time. In this case, a separate analysis is necessary to determine the potential for wind-driven mixing to disrupt density vertical stratification.

A common form of the Froude number (as shown in Appendix B) is presented by Tchobanoglous and Schroeder (Tchobanoglous, G. and Schroeder, E.D.,1987. *Water Quality: Characteristics-Modeling-Modification*. Addison-Wesley):

$$N_{DF} = \frac{Q/(b \times d)}{\sqrt{\left(\Delta\rho/\rho\right) \times g \times d}}$$

where

N_{DF} = densimetric Froude number
Q = Volume flow
b = Average basin width
d = Average basin depth
$\Delta\rho$ = Top and bottom water density difference
ρ = Depth-average water density
g = gravity constant

Values used to calculate the Froude number presented in Appendix B are as follows:

Q = 0.0128 m^3/s
b = 284 m
d = 29.8 m
$\Delta\rho$ = 0.000265 g/cm^3
ρ = 0.999832 g/cm^3
g = 9.81 m/s^2

Water densities are taken from temperature-density standard tables with surface water at 10 °C and deep water at 5 °C, reflecting typical conditions in the HTDF during October. Using these values, the value of the Froude number is 0.0000054, as reported in Appendix B. The very small value of N_{DF} indicates that the relatively low and gentle flows through the HTDF would not be sufficient to mix the large and deep basin.

It is important to note that because the Froude number for the HTDF is so much less than unity, the conclusions of the analysis do not change in response to reasonable changes in individual parameters. For example, doubling the average depth of the HTDF (to 60 m) results in a Froude number equal to 0.0000019, and halving the depth (to 15m) gives a Froude number equal to 0.000015. In each case, the Froude number is much less than unity, indicating mixing of the water column will not occur given the existing flows. The effect of increasing flows is examined later in this general response.

Additional work to evaluate the vertical stability of the HTDF was completed after publication of the *Humboldt Tailings Disposal Facility Hydrologic and Geochemical Mass Balance Report* (Mass Balance Report and Appendix B in this discussion). The additional work is described in a report entitled *Humboldt Mill Basin Integrity and Vertical Stability of the Humboldt Tailings Disposal Facility* (Vertical Stability Report), submitted with the *Humboldt Mill Mining Permit Application* as Volume II I. Findings of this report concerning HTDF vertical stability address the primary concern raised in Question 4, that is, the capacity of the HTDF to maintain vertical stratification and so minimize water column mixing. Excerpts from this report relevant to this discussion are presented below.

The Vertical Stability Report presents the results of four investigations that demonstrate vertical stability of the HTDF water column. These investigations were possible because of additional field sampling that occurred after publication of the Mass Balance Report and the initial Froude number calculation contained within that report. Specifically, depth profiles of relevant physical and chemical parameters were obtained on a quarterly basis over one year. These profiles allow the vertical structure of the HTDF water column to be examined across changing seasonal conditions. The four investigations are:

- Froude Number calculation for the HTDF during the time of year when mixing is most likely;
- Quarterly measurements with respect to water depth of HTDF water temperature and specific conductance;
- Calculation of quarterly water column density profiles;
- Year-on-year water column chemical depth profiles.

In all cases, the investigations indicated that the water column of the HTDF was very stable and that it is very unlikely that the bottom water of the HTDF will mix with overlying water. Specific results are summarized below.

Froude Number Calculation for the HTDF During the Time of Year When Mixing is Most Likely

The Froude number calculation presented above (and in Appendix B) used data available at the time the Mass Balance Report was produced. The availability of new data allowed the calculation to be redone using data from the month of April. Mixing due to water flow is most likely during April, as the HTDF experiences maximum flows through the basin due to melting winter snows, and temperature stratification (and thus, the temperature component of density stratification) is minimal. New values used for this calculation are:

$Q = 0.0392\ m^3/s$
$\Delta\rho = 0.000018\ g/cm^3$
$\rho = 0.999969\ g/cm^3$

Water densities in this calculation are based on a standard density-temperature-salinity relationship, as presented by Millero and Poisson (Millero, F.J., and A. Poisson. 1981. "International One-Atmosphere Equation of State for Sea Water." *Deep-Sea Research*, 28(6A):625-629) with salinity set to zero. Water temperatures are the average of values measured with three-foot resolution in April, 2008 at two central stations on the HTDF. Surface water temperature is the average temperature over the upper forty feet of water depth (5.42 °C); deep water temperature is the average of temperature values below forty feet (4.13 °C). Other values are as in the original calculation.

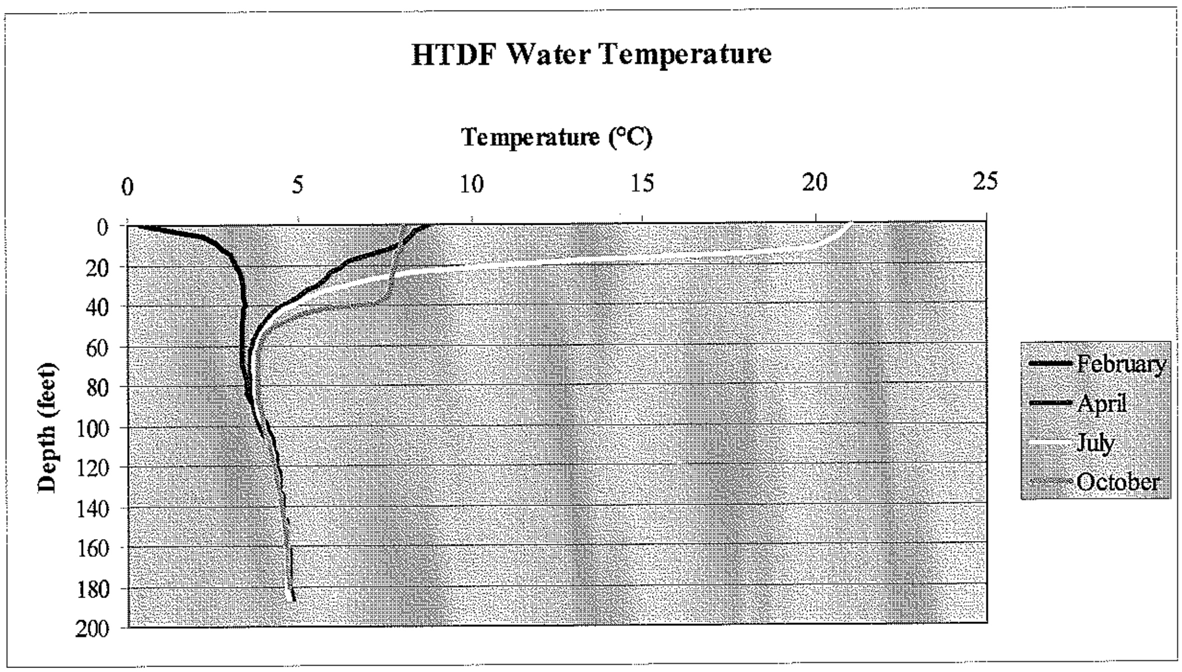
The Froude number during April (likely the near-maximum value for the annual cycle) is 0.000064. Though roughly ten times greater than the previous value under different ambient conditions, the Froude number remains much less than unity. This indicates that the HTDF basin experiences very little mixing due to bulk flow, and vertical gradients of temperature and concentration would be expected to form. Moreover, because of the small flow out of the facility compared to the cross-sectional area, the difference in density between top and bottom water must be less than about 10^{-10} before the Froude number approaches unity. This suggests that it is very unlikely that the HTDF will mix completely as a result of bulk flow.

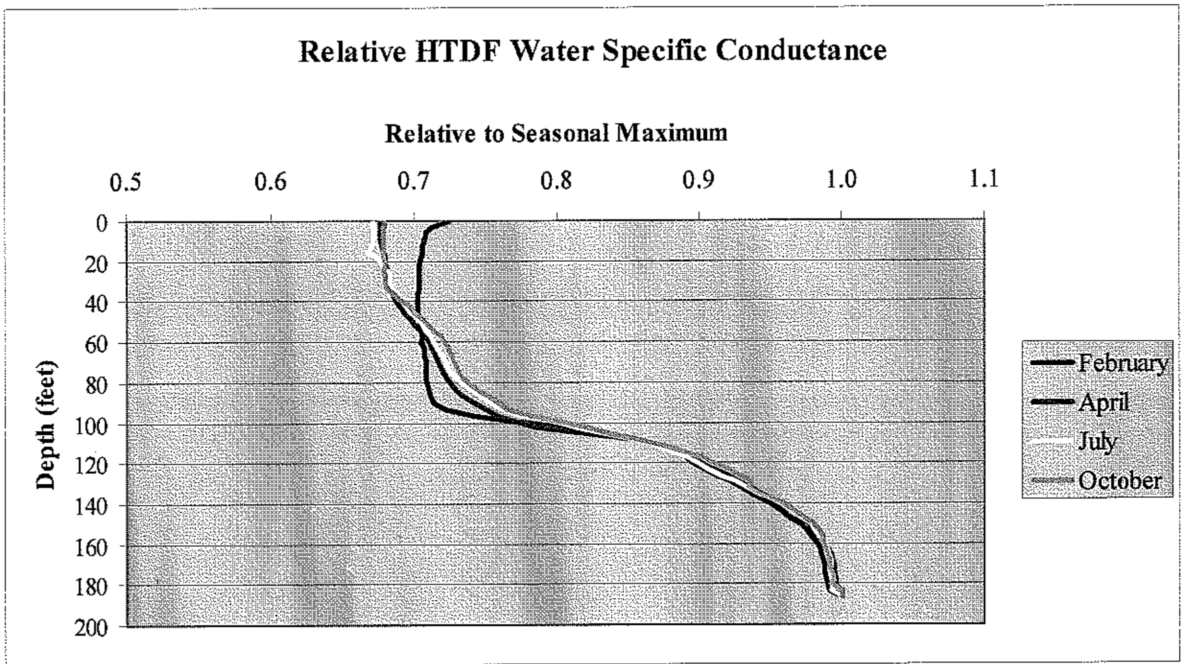
Quarterly Measurements With Respect to Water Depth of HTDF Water Temperature and Specific Conductance

The Froude number calculation, as presented here, considered water density differences due only to difference in water temperature. This is a conservative approach and will produce a maximum Froude number. However, density stratification may also be due to differences in salt concentrations in top and bottom waters. As stated in the Vertical Stability Report:

> Vertical stability in a body of surface water is a result of water density gradients, specifically gradients that increase with increasing depth, so that lower density water floats on higher density water. Water density is affected by both temperature and concentration of total dissolved solids (TDS); density decreases with increasing temperature, but increases with increasing TDS. Thus, water column vertical stability can be due to warm water on top of cold water, low TDS water on top of high TDS water, or a combination of these two conditions.

Quarterly measurements of temperature and TDS concentration depth profiles provide data necessary to consider both components of density stratification in the HTDF. The relatively constant shape of these depth profiles across seasons provides evidence that the water column of the HTDF does not completely mix. The temperature and specific conductance depth profiles are displayed below. Note that specific conductance values are plotted relative to the maximum value in each seasonal data set so that seasonal trends are most visible.





It is apparent from the seasonal temperature profiles that the surface water of the HTDF probably mixes annually as the thermocline collapses. However, the maximum mixing depth, based on these data, is about sixty feet and the very uniform deep temperatures suggest that bottom water does not mix. This characterization is strongly supported by the specific conductance data, which demonstrate the presence of two discrete zones in the water column with very stable but different TDS (salt) concentrations. This type of water column structure is a defining feature of a meromictic system, that is, a system with perennially isolated bottom water.

The Vertical Stability Report summarizes the above data as follows:

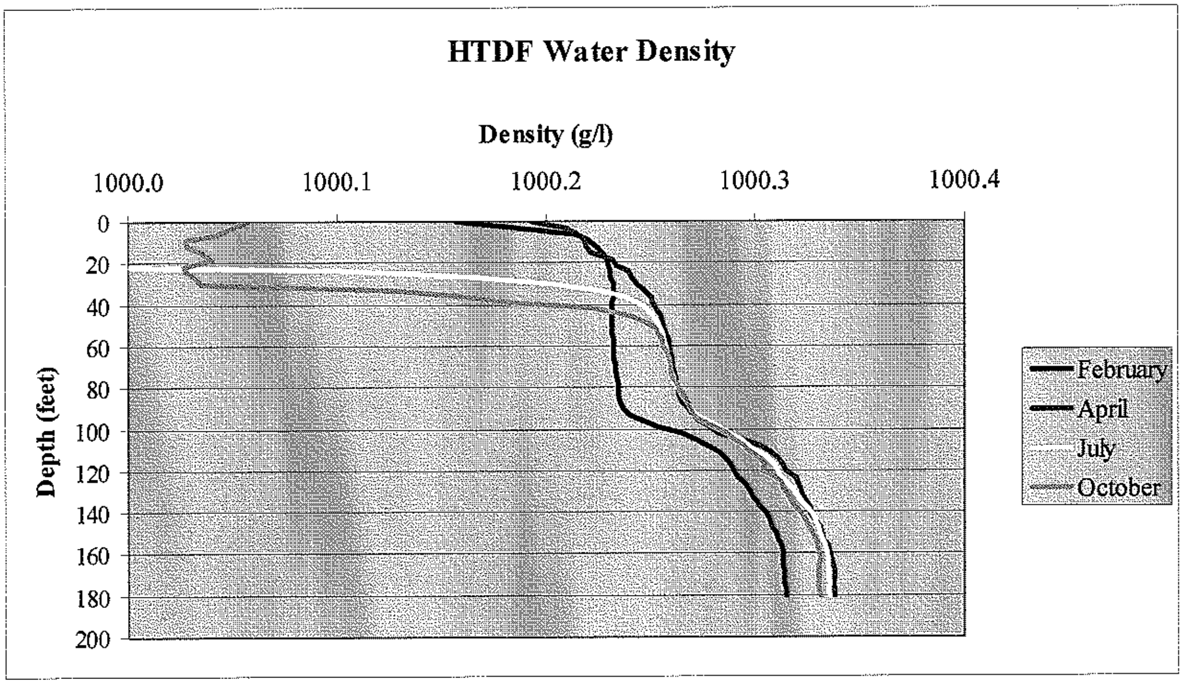
> Field measurements collected quarterly during 2008 demonstrate the presence of vertical gradients of water temperature and specific conductance. Each of these gradients displays an area of rapidly changing values at a unique depth in the water column. Thus, the temperature profile is segmented into an upper and lower portion by a thermocline; at a deeper depth, the specific conductance profile is segmented by a chemocline. Each of these features greatly restricts vertical mixing, and therefore strengthens the vertical stability of the water column. Although the thermocline is seasonal, the chemocline is perennial.

The report also presents a more detailed discussion of the above profiles and concludes that the HTDF is most probably a meromictic system. It is also noted that the perennial TDS chemocline will be reinforced by the addition of new tailings and associated carriage water at the bottom of the HTDF, and that the position of the chemocline may rise somewhat in the water column, thereby providing ongoing vertical stability to the shallower water column.

Calculation of Quarterly Water Column Density Profiles

While temperature and specific conductance depth profiles provide strong evidence of a stable HTDF water column across seasons, the most direct indication of a meromictic system (and, therefore, one that does not completely mix) is provided by seasonal density profiles of the HTDF water column. Water density as a function of water depth is presented in the Vertical Stability Report.

Water density was calculated by combining information obtained by measuring temperature (as shown above) and TDS concentrations. Although TDS measurements were only available for five water depths, TDS measurements were strongly correlated with measurements of specific conductance. Thus, high resolution specific conductance depth profiles were used to generate high resolution TDS depth profiles. Temperature and TDS concentrations were then combined using standard procedures (Millero and Poisson, as referenced above) to calculate seasonal water density depth profiles. The results are displayed below (the July surface density minimum is not shown; surface water density during this period fell to about 998.5 grams per liter).



The density profiles clearly show the perennially elevated bottom water density and support the assertion that the HTDF is a meromictic system. It is very likely that the bottom water of the HTDF is permanently stratified and unable to mix with overlying water. And, as demonstrated by model outcomes in the Mass Balance Report, controlled placement of new tailings at the bottom of the HTDF will preserve density stratification despite decreased water depth.

Year-On-Year Water Column Chemical Depth Profiles

As discussed in the Mass Balance Report, the bottom waters of the HTDF contain elevated concentrations of a number of water quality parameters relative to surface concentrations of these parameters. The Vertical Stability Report presents a comparison of two sets of these profiles collected in different years. The nearly identical concentrations and depth profile shapes for each water quality parameter, with two exceptions, is difficult to explain if complete mixing occurred between the times each data set was collected. The Vertical Stability Report provides this summary of the year-on-year profiles:

> The vertical stability of the HTDF water column is demonstrated by comparison of year-on-year depth profiles of twenty chemical parameters. In all cases but two, the depth profiles for a given chemical parameter are nearly identical between 2007 and 2008. The two profiles with significant differences are associated with iron and total organic carbon; each of these receives allochthonous inputs. It is unlikely that this degree of similarity would be present if the HTDF were to mix fully. Thus, the similarity of depth profiles on annual time scales indicates a high degree of vertical stability in the HTDF water column.

In summary, the Vertical Stability Report provides a much more complete assessment of the vertical stability of the HTDF water column than that offered by the Froude number analysis presented in the Mass Balance Report. However, each assessment concludes that the water column has a high degree of vertical stability and will maintain this stability during and after the loading of new tailings.

It is recognized that neither assessment addresses the effect of wind-driven mixing on stability. An analysis of mixing due to wind is presented below in response to specific questions.

Answers to Specific Questions

4a. Has equation (4) been field validated for applicability to temperate lakes?

Predictions based on the Froude number compare favorably to actual behavior of lakes and reservoirs in many climates. The Froude number analysis is semi-quantitative in that values near unity are indeterminate. Values greater or less than unity provide meaningful results, and these results have been verified through observations of many water basins at many latitudes. A background reference is provided by Chu and Baddour (Chu, V.H. and Baddour, R.E. 1984. Turbulent gravity-stratified shear flows, *Journal of Fluid Mechanics*, 138:353-378).

4b. How are wind forces taken into account in the inputs to equation (4)?

As discussed above in the general discussion section, the Froude number (equation (4)) does not address wind-driven mixing. However, an analysis of wind-driven mixing in the HTDF has been prepared and is presented here. The analysis includes an examination of the effect of depth on wind-driven water column mixing in the HTDF.

The magnitude of wind-driven mixing in surface water is a function of wind speed, direction, and duration; fetch distance and basin morphology; and density gradients within both air and water. Wind-induced turbulence manifests initially as gravity waves on the water surface. A preliminary analysis of wind-induced water column turbulence is often based on an analysis of wave height, wave period, and wave length. The analysis presented here is based on the following references:

Wetzel, R.G. 2001. *Limnology, 3rd ed.* Academic Press, New York.
Chapra,S.C. 1997. *Surface Water-Quality Modeling.* WCB McGraw-Hill, Boston.

Methods presented here require as input wind speed, mean basin depth, and fetch distance. Wind speeds are measured at the Champion-Van Riper State Park, about six miles from the HTDF, and reported by the Michigan Department of Agriculture, Climatology Program. Long-term average wind speed is 4.0 meters per second (m/s) (9 miles per hour (mph)), prevailing westerly. The highest one minute gust on record (June 1958) was 26.4 m/s (59 mph). An assumed maximum sustained wind of 17.9 m/s (40 mph) is used in the following calculations.

Two-thirds of the basin area of the HTDF is deeper than 20 meters (m) (66 feet) and a hypothetically shallow HTDF basin might be 3 to 5 m deep. Each of these values is used in the following calculations as mean basin depth.

The maximum fetch, given a wind from the south-southwest, across the HTDF surface is about 914 m (3000 feet).

The following equations are taken from Chapra (1-3) and Wetzel (4 and 5):

$$H_S = 0.283\frac{U^2}{g}\tanh\left[0.53\left(\frac{gH}{U^2}\right)^{0.75}\right]\tanh\left\{\frac{0.0125\left(\frac{gF}{U^2}\right)^{0.42}}{\tanh\left[0.53\left(\frac{gH}{U^2}\right)^{0.75}\right]}\right\} \tag{1}$$

$$T_S = 1.2\frac{2\pi U}{g}\left[0.833\left(\frac{gH}{U^2}\right)^{0.375}\right]\tanh\left\{\frac{0.077\left(\frac{gF}{U^2}\right)^{0.25}}{\tanh\left[0.833\left(\frac{gH}{U^2}\right)^{0.375}\right]}\right\} \tag{2}$$

$$L_O = \frac{gT_S^2}{2\pi} \tag{3}$$

$$H_{MAX} = 0.105\sqrt{F*100} \tag{4}$$

$$D_d = H_{MAX}\left(0.5^{\frac{9d}{L_O}}\right) \tag{5}$$

where
H_S = significant wave height (m)
T_S = significant wave period (s)
U = wind speed (m/s)
H = mean depth (m)
F = fetch (m)
L_O = wavelength (m)
H_{MAX} = maximum wave height (cm)
D_d = vertical displacement (cm) at depth d (m) below water surface

The more rigorous solutions for wave height, period and wavelength (taken from Chapra and represented by equations 1 – 3) are solved for the surface of the HTDF using values for wind speed, mean depth, and fetch presented above. Results for wave height and wavelength at three mean depths are shown in Table 1.

Table 1
HTDF Calculated Wave Height and Wavelength

Mean HTDF Depth (m)[1]	Wave Height (m)[2]	Wavelength (m)
3	0.42	7.73
5	0.45	8.13
20	0.47	8.76

[1]Actual HTDF mean depth is near 30 m. Shallow depths are hypothetical.
[2]Wave height is constant at mean depths greater than 20 meters.

Wetzel presents a solution for maximum wave height that depends only on fetch length, as shown in Equation 4. Using the HTDF maximum fetch of 914 m, the predicted maximum wave height is 0.32 m. Given the simplicity of this estimate, the predicted wave height is in excellent agreement with, and validates, the values predicted by the more rigorous solutions.

Turbulence energy delivered by wind is transferred to a body of water as gravity waves crest and break. Thus, the magnitude of the oscillation of the water surface moving between wave crest and trough (equal to wave height) provides a measure of the level of turbulence on the surface of the water. Of particular interest here is the amount of surface turbulence that is transferred to deeper water. Wetzel (and others) state that turbulent energy is rapidly attenuated with increasing water depth. The turbulence at water depth d, as represented by the fraction of original surface oscillation (or displacement) remaining at depth, is proportional to the wavelength of the original oscillation, as shown in Equation 5. Table 2 displays the magnitude of the displacement (and hence, the amount of turbulence) at several depths below the surface of the HTDF. These values were calculated using the maximum predicted wave height for the HTDF (0.47 m), and so represent maximum turbulence at depth. Table 2 also shows displacement at depth as a percentage of the original wave height.

Table 2
HTDF Turbulence at Depth – Represented by Vertical Displacement

Water Depth (m)	Displacement (cm)	Percent of Wave Height[1]
2	11.2	24
5	1.32	3
7	0.32	0.6
10	0.04	0.08

[1]Initial wave height in all cases is 0.47 meters.

The values in Table 2 show how rapidly surface turbulence (as represented by wave height) dissipates in the HTDF with increasing water depth. Essentially all surface turbulence has dissipated after traversing 7 m (23 feet) of water depth. The wave height used to generate the modeled turbulence is near a theoretical maximum for the HTDF basin (sustained 40 mph wind from the south-southeast traversing the maximum fetch distance); typical values for the facility would create less turbulence that would dissipate at shallower depths than those shown in Table 2. It is also important to note that topography of land surrounding the HTDF will attenuate the wind speed reaching the surface of the HTDF. This effect was ignored in this conservative calculation.

Based on the above analysis, wind-driven turbulence may induce mixing in, at most, the first thirty feet of HTDF water. It is noted that this depth is in reasonable agreement with the depth of the HTDF thermocline and seasonal changes in surface water temperatures.

> *4c. Why did mixing apparently occur in the past (as evidenced by high DO levels at the bottom) when the HTDF was deeper? How will decreasing the depth of the HTDF by another 75 feet affect the N_{DF}?*

Given the history of the HTDF, the presence of oxygen in deep water of the original Humboldt pit does not necessarily imply that the entire water column was mixed. The Humboldt pit began to flood in about 1968 and reached its current depth in about 1981. During much of this time, oxygenated surface run-off was flowing down the walls of the pit and accumulating at the base of the pit. Thus, oxygenated water filled the pit over years of time. Field evidence shows that allochthonous organic carbon inputs to the original pit and the current HTDF are minimal. Also, investigations in the mid-1980s reported that the flooded pit supported very little life. Therefore, reductants that might consume dissolved oxygen may not have been plentiful. Limited oxygen consumption also means that continual diffusion of atmospheric oxygen would help sustain dissolved oxygen levels. It is entirely likely that in the absence of enough organic carbon to consume oxygen, HTDF bottom water retained dissolved oxygen for an extended period of time (years) after the pit flooded. For these reasons, it is possible that elevated oxygen levels (roughly 50% of saturation values) in the bottom water of the recently flooded pit were a result of processes other than water column mixing.

It is also noted that potential mixing of the early pit does not imply that the shallower HTDF will mix. As discussed in the general discussion section above, vertical stability of the HTDF is greatly enhanced by the presence of a TDS chemocline. The elevated TDS concentrations in HTDF bottom water are probably a result of the loading of Ropes mine tailings in the late 1980s. This fundamental change in the Humboldt pit as it became the HTDF makes comparison of the two systems less meaningful.

As demonstrated in the general discussion section above, changes in water depth have little effect on the outcome of the Froude number analysis of mixing due to bulk flow, as the HTDF Froude number is inherently small (indicating very little mixing due to flow). This is a result of basin morphology and flow through the system. At a hypothetical mean depth of five meters (16 feet), and given the other values used in the original Froude number calculation presented in the Mass Balance Report, the Froude number is equal to 0.000079. This value remains much less than unity, and complete mixing due to bulk flow of even this hypothetically shallow HTDF is not possible.

> *4d. The equation indicates that N_{DF} should become larger as the volume flow (Q) increases. How will the displacement of water from the discharge of tailings affect the value of Q and ultimately N_{DF}?*

The value of N_{DF} does increase with increasing flow. However, as with depth, reasonable increases in flow will have little effect on the outcome of the Froude number analysis of the HTDF. Current annual average flow out of the HTDF is roughly 250 gallons per minute (gpm). The Mass Balance Report presents modeled flows out of the HTDF as new tailings are loaded into the facility. Maximum annual average flow during tailings loading is about 500 gpm. If a flow of 1000 gpm (0.063 m^3/s) is combined with the other values used in the original Froude number calculation presented in the Mass Balance Report, the Froude number is equal to 0.000027 and the analysis indicates that this level of flow will not cause mixing of the HTDF water column.

> *4e. With wind, decreased depth, and increased outflow taken into account, would you still predict a stable system?*

The above discussion has demonstrated that reasonable decreases in depth and increases in flow, like those associated with loading of new tailings, are insufficient to bring about complete mixing of the HTDF. The analysis of wind-driven mixing indicates that surface waters of the HTDF may mix to about thirty feet under strong and sustained winds, but this mixing will not affect the entire water column. Also, the HTDF exhibits characteristics of a meromictic system, with a permanently stratified layer of water containing high TDS concentrations at the bottom of the facility. The addition of new tailings and carriage water at the bottom of the HTDF will further increase the TDS levels in the bottom water, and thereby strengthen the vertical stability of the water column. The Mass Balance Report presents results from a numerical model of the HTDF before, during and after loading with new tailings. In all cases, and given proper loading methodologies as outlined in the report, the HTDF water column maintains vertical stability. Thus, a stable system is predicted.

ATTACHMENT 3

Response to USFSW and EPA Wetland Questions

Rio Tinto

Kennecott Eagle Minerals
Victoria Peacey
HSE Manager
504 Spruce Street
Ishpeming, Michigan 49849
(906) 486-1257

August 13, 2009

Mr. Mike Smolinski
Michigan Department of Environmental Quality
Land and Water Management Division
420 5th Street
Gwinn, MI 49841

Dear Mr. Smolinski:

Re: **Response to Comment on Kennecott Eagle Minerals Company Humboldt Mill Joint Permit Application for an Inland Lakes and Streams (ILSA) Permit, File Number 08-52-0104-P**

In two separate communications dated June 23, 2009 and July 2, 2009 a request for clarification/information was received from the Michigan Department of Environmental Quality (MDEQ) Land and Water Management Division (LWMD). The letter dated July 2, 2009 contained comments from the U.S. Fish and Wildlife Service (USFWS) and the U.S. Environmental Protection Agency (EPA) dated May 27, 2009 and June 19, 2009 respectively.

Attached, please find a completed response to the June 23, 2009 MDEQ comments and a partial response to comments from USFWS and EPA. A completed response to all questions from the USFWS and the EPA will be provided in a separate letter.

Should you have any questions please don't hesitate to contact me at 906-486-1257.

Sincerely,

Vicky Peacey

Vicky Peacey
HSE Manager

cc: Joe Maki, MDEQ
Dennis Donohue, Warner Norcross and Judd, LLC
Matt McGregor, King and McGregor Environmental, Inc
Aaron Graham, M3 Engineering and Technology Corp.
Jon Cherry, Kennecott Eagle Minerals Company
Alicia Duex, Kennecott Eagle Minerals Company
Kris Baran, Foth Infrastructure and Environment, LLC

File: EC-Humboldt-ILSA-Corres to MDEQ

Responses to Comments

Comments from MDEQ LWMD, USFWS and EPA are in italics and KEMC responses are in regular text. Due to the similarity in the comments raised by MDEQ, USFWS and EPA, the response to all questions has been addressed collectively.

June 23, 2009 Comments from MDEQ LWMD

- *What impact will the increased pumping (flows) have on wetland EE?*
- *Will it raise the water levels within the wetland and how much?*
- *Will the culvert under US 41 handle the flow?*

May 27, 2009 Comments from USFWS: Discharge of Waste Water into Adjacent Wetlands

- *In addition to our concerns about disposal of the tailings in the HTDF, we also have concerns about the applicant's proposal to discharge 13,500 cubic feet of treated water per day into adjacent wetlands. We have concerns that this increased volume of water into the wetlands will make the area too wet to continue to support an emergent/scrub-shrub community, changing the wetland to an open water system. We recommend the applicant demonstrate that this increased volume would not affect the plant community or else consider alternatives to discharging treated water into the wetlands. We recommend compensatory mitigation for any unavoidable impacts to the adjacent wetlands, including conversion of another wetland type.*

June 19, 2009 Comments from EPA

- *It has been well documented that increases in volume and/or frequency of surface water inputs to wetlands can degrade wetland plant communities. In this case, the addition of a significant amount of water to the wetlands is likely to result in the degradation and/or destruction of the vegetated wetlands community, possibly resulting in the creation of a large open water area. The conversion of a vegetated wetland community to open water would result in habitat loss and possibly water quality benefits as well. The applicant needs to demonstrate that there are no alternatives available that would be less damaging to these wetlands. If no alternative is available, than pursuant to the Section 404(b)(1) Guidelines, the applicant needs to mitigate for unavoidable adverse impacts.*

KEMC Response:

Please see Attachment A and Attachment B for a detailed response to all questions from LWMD, USFWS and EPA.

ATTACHMENT A

Wetland EE Vegetative Community Evaluation

King & MacGregor Environmental, Inc.
2520 Woodmeadow Drive SE
Grand Rapids, MI 49546
Phone (616)957-1231 • Fax (616) 957-2198

MEMO

To: Victoria Peacey, HSE Manager, Kennecott Eagle Minerals

From: Matthew MacGregor

Date: August 12, 2009

Subject: Wetland EE Vegetative Community Evaluation

In a May 27, 2009 letter, the U.S. Fish & Wildlife Service expressed concern that the proposed daily discharge of up to 13,500 cubic feet of treated water to the existing wetland (Wetland EE) located directly north of the Humboldt Tailings Disposal Facility would affect the character of the vegetative community and/or create a large open water area within Wetland EE.

King & MacGregor Environmental, Inc. conducted a wetland delineation of the subject wetland during the summer of 2007. The subject wetland is approximately 11.8 acres in size and is bounded on the south by a steep rocky grade and on the north by US 41. This wetland is part of a much larger wetland system located north of US 41. The subject wetland is predominately an emergent marsh dominated by broad-leafed cattail (*Typha latifolia*) with a narrow edge of scrub-shrub wetland dominated by balsam willow (*Salix pyrifolia*). The wetland contains several open water areas; the largest is approximately 1.7 acres in size. The subject wetland is groundwater fed, also receiving water inputs from surface water runoff and direct precipitation. Surface water leaves this wetland through three existing culverts under US 41. These culverts and existing ground contours regulate the surface water elevations within Wetland EE.

At the request of Kennecott Eagle Minerals Company, M3 Engineering & Technology Corporation (M3) conducted an analysis of water flow within Wetland EE. This analysis considered water elevation, inundation duration and culvert backwater condition during the existing condition, no storm, 5 year, 25 year, 50 year and 100-year storm events. This analysis determined that during these storm events, the treated water discharge will add less than 0.1 ft to the existing storm headwater elevations at the culvert inlet, and thus the water elevation increase in Wetland EE will also be less than 0.1 ft. Additionally, increases in headwater elevations at the culvert and in Wetland EE during these storm events will return to normal in less than 8 hours.

M3 also conducted an evaluation to determine if the proposed discharge would cause any backwater effect at the existing culverts. It was determined that the water surface elevation will increase between 0.16 feet and 0.22 feet during the proposed waste water treatment plant discharge (non-storm conditions analyzed). This increase in water elevation is associated with the culvert backwater effect and would be limited to a small area near each culvert. Due to the small, localized increase in water elevation at the culvert inlet, it is unlikely that any measurable increase in water elevation would be observed elsewhere in Wetland EE.

The treated water will be discharged through on outlet structure to Wetland EE. The outlet structure has been designed to keep water velocities below erosive rates. The designed discharge velocity is 0.5 feet per second. This discharge velocity will not scour or erode the wetland soils or create additional open water areas within Wetland EE.

The effect of water elevation fluctuation on cattail marshes is well documented. Several studies have been conducted within the last decade that assess methodologies used to control or modify cattail stands (Apfelbaum, 2005). High water conditions in a cattail stand can affect the growth of seedlings, can break off mature stalks, or can be followed by the immigration of muskrats which eat the cattail. The effect of flooding does not always have negative impacts on cattails; plants have been known to float and continue growing until water returns to previous levels. Temporary conditions, such as flooding, do not prevent later seed establishment. In one study, two years of 65 cm (26 inches) deep flooding was required before established cattail began to die and open water conditions were created. Another study found that mature cattail and seedlings less than one year old are killed by water depths of 63.5 cm (25 inches) and 45 cm (18 inches) or more, respectively. The scrub- shrub edge of the subject wetland is dominated by willow species. Willow is well adapted to riparian habitats. Temporary flooding would have minimal impact on these species.

Based on the M3 analysis, the proposed modifications to the water elevation, duration of inundation and water velocity are not of a magnitude to negatively affect the cattail-dominated plant community of Wetland EE. The values and functions provided by Wetland EE will be maintained after completion of the proposed construction.

Reference

Apfelbaum, S. I., Undated, Cattail (*Typha* spp.) Management, Applied Ecological Services, Brodhead, Wisconsin